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REMARKS

In the office action, the examiner rejects all claims as obvious over Jeffryes in view of Andersen. With regard to claim 1, the examiner uses the same words as he used in rejecting the claims over the same art in the earlier PCT Written Opinion (copy enclosed). The applicants point out that they responded to that Written Opinion (copy of Response enclosed), amending the claims and arguing the rejections. The claim amendments increased the number of claims from 9 to 21. This resulted in an IPRP (copy enclosed) finding claims 1-19 and 21 both novel and inventive and also having industrial applicability. The IPRP lists the present examiner as authorized officer.

The applicants believe that the most recent examination took place without the benefit of the PCT prosecution that followed the issuance of the Search Report and the Written Opinion. Accordingly, the applicants respectfully request reconsideration and reissue of the first office action.

PAGE 4/36 * RCVD AT 8/10/2007 4:27:28 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/21 * DNIS:2738300 * CSID:713 431 4664 * DURATION (mm-ss):13-02

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CONCLUSION

If the examiner has any questions, please contact the undersigned attorney.

Respectfully submitted,

Date: 10 August 2007

J. Paul Plummer

J. Paul Plummer
Reg. No. 40,775

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Certification under 37 CFR §§ 1.8(a) and 1.10

I hereby certify that, on the date shown below, this application/correspondence attached hereto is being:

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EXXONMOBIL URC LAW 713 431 4664 P.02

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
J. PAUL PLUMMER
EXXONMOBIL UPSTREAM RESEARCH COMPANY
P.O. BOX 2189
HOUSTON, TX 77252-2189

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing (*day/month/year*) 03 JAN 2005		
Applicant's or agent's file reference 2003UR020	FOR FURTHER ACTION See paragraph 2 below	
International application No. PCT/US04/17335	International filing date (*day/month/year*) 03 June 2004 (03.06.2004)	Priority date (*day/month/year*) 11 August 2003 (11.08.2003)
International Patent Classification (IPC) or both national classification and IPC IPC(7): G01V 1/28 and US CL.: 367/41, 46, 43, 38, 40, 189		
Applicant KROHN, ET AL		

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis(b)* that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/ US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	23 November 2005 (23.11.2005)	Scott A. Hughes [signature] Telephone No. 571-272-6983

Form PCT/ISA/237 (cover sheet) (April 2005)

PAGE 6/36 * RCVD AT 8/10/2007 4:27:28 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/21 * DNIS:2738300 * CSID:713 431 4664 * DURATION (mm-ss):13-02

EXXONMOBIL URC LAW 713 431 4664 P.03

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US04/17335

Box No. I Basis of this opinion

1. With regard to the language, this opinion has been established on the basis of:
   - ☒ the international application in the language in which it was filed
   - ☐ a translation of the international application into ______, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. With regard to any nucleotide and/or amino acid sequence disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:
   a. type of material
      - ☐ a sequence listing
      - ☐ table(s) related to the sequence listing
   b. format of material
      - ☐ on paper
      - ☐ in electronic form
   c. time of filing/furnishing
      - ☐ contained in the international application as filed.
      - ☐ filed together with the international application in electronic form.
      - ☐ furnished subsequently to this Authority for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table(s) relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Form PCT/ISA/237(Box No. I) (April 2005)

713 431 4664 P.04

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US04/17335

Box No. V Reasoned statement under Rule 43 *bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 1-9	YES
	Claims none	NO
Inventive step (IS)	Claims NONE	YES
	Claims 1-9	NO
Industrial applicability (IA)	Claims 1-9	YES
	Claims NONE	NO

2. Citations and explanations:

Please See Continuation Sheet

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713 431 4664 P.05

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US04/17335

Supplemental Box
In case the space in any of the preceding boxes is not sufficient.

V. 2. Citations and Explanations:
Claims 1-9 lack an inventive step under PCT Article 33(3) as being obvious over Jeffryes in view of Anderson.

With regard to claim 1, Jeffryes discloses a method of operating a plurality of N seismic vibrators simultaneously with continuous sweeps, and separating the seismic response for each vibrator (abstract). Jeffryes discloses loading each vibrator with a unique continuous sweep consisting of M (greater than or equal to) N segments, the ith segment being of the same duration for each vibrator (Page 5, Line 4 to Page 6, Line20, Pages 7-8,10). Jeffryes discloses activating all vibrators and using at least one detector to detect and record the combined seismic response signals from all vibrators (Page 10). Jeffryes discloses selecting and recording a signature for each vibrator indicative of the motion of that vibrator (Page 10, Line 8 to Page 11). Jeffryes discloses parsing the vibrator motion record for each vibrator into M shorter recorders, each shorter recording coinciding in time with a sweep segment (Page 11, Lines 1-20). Jeffryes discloses padding response signals but does not disclose padding the shorter records of the vibrator motion record to substantially extend its duration by one listening time (Pages 18-19). Anderson discloses padding seismic signals by one listening time when using a continuous sweep consisting of M segments. (Column 4, Lines 20 to Column 5, Line 20; Column 6, Lines 10 to 60; Column 8; Columns 12-14). It would have been obvious to modify Jeffryes to pad the signals with time up to the listening time as taught by Anderson in order to be able to process the data with a correlation reference sequence. Jeffryes discloses forming an M by N matrix whose element Sij(t) is the vibrator motion record as a function of time of the ith vibrator and jth sweep segment (Pages 5-7; 10-11, 14-16, 20-22). Jeffryes discloses parsing the seismic data record from above into M short records, each shorter record coinciding in time with a padded shorter record of vibrator motion from step d). Jeffryes discloses forming a vector d of length M whose element di is the ith shorter data recorder from the preceding step. Jeffryes discloses solving for Ej(f) the system of M linear equation in N unknown SE=D. Jeffryes discloses inverse Fourier transforming Ej(f) to yield ej(t) (Pages 10-11, 14-16, 19-20).

With regard to claim 2, Jeffryes discloses that each sweep segment is selected from linear sweep-design (Page 10, Lines 5-15).

With regard to claim 3, Jeffryes discloses that all of the N unique continuous sweeps are identical except for the phase of their segments (Page 10, Lines 15-25).

With regard to claim 4, Jeffryes discloses that all N segments are identical except for phase. Jeffryes discloses constructing a reference sweep by starting with a preselected reference segment, then advancing the segment 360/M degrees in phase to make the second segment, then advancing the phase 360/M degrees more to make the third segment, and so on to generate M segments. Jeffryes discloses constructing a first sweep by advancing the phase of the first segment of the reference sweep by 90 degrees. Jeffryes discloses constructing a second sweep by advancing the phase of the second segment of the reference sweep by 90 degrees and so on until all N sweeps are constructed (Page 7).

PAGE 9/36 * RCVD AT 8/10/2007 4:27:28 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/21 * DNIS:2738300 * CSID:713 431 4664 * DURATION (mm-ss):13-02

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US04/17335

Supplemental Box
In case the space in any of the preceding boxes is not sufficient.

With regard to claim 4, Anderson discloses that all N segments are identical except for phase. Anderson discloses constructing a reference sweep by starting with a preselected reference segment, then advancing the segment 360/M degrees in phase to make the second segment, then advancing the phase 360/M degrees more to make the third segment, and so on to generate M segments. Anderson discloses constructing a first sweep by advancing the phase of the first segment of the reference sweep by 90 degrees. Anderson discloses constructing a second sweep by advancing the phase of the second segment of the reference sweep by 90 degrees and so on until all N sweeps are constructed (abstract; Columns 4, 6).

With regard to claim 5, Anderson discloses that each unique continuous sweep has a duration in time sufficiently long to collect all seismic data desired before relocating the vibrators (Columns 4, 6).

With regard to claim 6, Jeffryes discloses that the vibrator signature record for each vibrator is a weighted sum or ground force record of the motion of that vibrator (Page 4, Lines 5-14; Pages 10-12).

With regard to claim 7, Jeffryes discloses that M=N and that the system of linear equation SE=D is solved by matrix methods comprising the steps of deriving a separation and inversion filter by inverting matrix S then performing the matrix multiplication (Page 8, Lines 1-5; Pages 11-19).

With regard to claim 8, Jeffryes discloses that SE=D is solved by matrix methods and the method of least squares comprising the steps of deriving a separation and inversion filter of the form F=(S*S)-1S* then performing the matrix multiplication FD (Page 8, Lines 1-5; Pages 11-19).

With regard to claim 9, Jeffryes discloses that each segment has a duration that is at least as long as the seismic wave travel time down to and back up from the deepest reflector of interest (Page 1).

Form PCT/ISA/237 (Supplemental Box) (April 2005)

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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 2003UR020	FOR FURTHER ACTION	See Form PCT/IPEA/416
International application No. PCT/US04/17335	International filing date *(day/month/year)* 03 June 2004 (03.06.2004)	Priority date *(day/month/year)* 11 August 2003 (11.08.2003)
International Patent Classification (IPC) or national classification and IPC IPC: G01V 1/28(2006.01) USPC: 367/41,46,43,38,40,189		
Applicant EXXON MOBILE UPSTREAM RESEARCH COMPANY		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 7 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *(sent to the applicant and to the International Bureau)* a total of 5 sheets, as follows:
      - ☐ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      - ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.

   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) _____ , containing a sequence listing and/or tables related thereto, in electronic form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).
4. This report contains indications relating to the following items:
   - ☒ Box No. I — Basis of the report
   - ☐ Box No. II — Priority
   - ☐ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - ☐ Box No. IV — Lack of unity of invention
   - ☒ Box No. V — Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - ☐ Box No. VI — Certain documents cited
   - ☐ Box No. VII — Certain defects in the international application
   - ☐ Box No. VIII — Certain observations on the international application

Date of submission of the demand 08 February 2006 (08.02.2006)	Date of completion of this report 07 September 2006 (07.09.2006)
Name and mailing address of the IPEA/ US Mail Stop PCT, Attn: IPEA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	for Authorized officer Scott Hughes Telephone No. 571-272-6983

Form PCT/IPEA/409 (cover sheet)(April 2005)

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY	International application No. PCT/US04/17335

Box No. I Basis of the report

1. With regard to the **language**, this report is based on:
   - [x] the international application in the language in which it was filed.
   - [ ] a translation of the international application into ______, which is the language of a translation furnished for the purposes of:
     - [ ] international search (under Rules 12.3 and 23.1(b))
     - [ ] publication of the international application (under Rule 12.4(a))
     - [ ] international preliminary examination (under Rules 55.2(a) and/or 55.3(a))

2. With regard to the **elements** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:
   - [ ] the international application as originally filed/furnished
   - [x] the description:
     pages 1-16 as originally filed/furnished
     pages* NONE received by this Authority on ______
     pages* NONE received by this Authority on ______
   - [x] the claims:
     pages 17 and 18 as originally filed/furnished
     pages* NONE as amended (together with any statement) under Article 19
     pages* 19, 19/1, 19/2, 19/3, 19/4 received by this Authority on 08 February 2006 (08.02.2006)
     pages* NONE received by this Authority on ______
   - [x] the drawings:
     pages 1/7 to 7/7 as originally filed/furnished
     pages* NONE received by this Authority on ______
     pages* NONE received by this Authority on ______
   - [ ] a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing.

3. [ ] The amendments have resulted in the cancellation of:
   - [ ] the description, pages ______
   - [ ] the claims, Nos. ______
   - [ ] the drawings, sheets/figs ______
   - [ ] the sequence listing (*specify*): ______
   - [ ] any table(s) related to the sequence listing (*specify*): ______

4. [ ] This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - [ ] the description, pages ______
   - [ ] the claims, Nos. ______
   - [ ] the drawings, sheets/figs ______
   - [ ] the sequence listing (*specify*): ______
   - [ ] any table(s) related to the sequence listing (*specify*): ______

* *If item 4 applies, some or all of those sheets may be marked "superseded."*

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY	International application No. PCT/US04/17335

Box No. V **Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims 1-19 and 21	YES
	Claims 20	NO
Inventive Step (IS)	Claims 1-19 and 21	YES
	Claims 20	NO
Industrial Applicability (IA)	Claims 1-21	YES
	Claims NONE	NO

2. Citations and Explanations (Rule 70.7)

Claims 1-19 and 21 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest operating a plurality of seismic vibrators with continuous sweeps as described in the claimed steps of claims 1, 10, 11 and 21including parsing the vibrator motion into M shorter records and padding the end of each shorter record as described in the claims. The prior art also does not show forming a vector d of length M as described in the claims.

Claim 20 lacks novelty under PCT Article 33(2) as being anticipated by Sallas.
With regard to claim 20, Sallas discloses a method of operating a plurality of N seismic vibrators Va-Vd simultaneously with continuous sweeps, so that the seismic response of each vibrator can be separated (Column 2; Column 5, Line 59 to Column 6, Line 6; Column 7, Line 22 to Column 8, Line 65; Columns 11-12). Sallas discloses loading each vibrator with a unique continuous sweep signal consisting of M greater than or equal to N segments, the ith segment being of the same duration for each vibrator with i=1, 2, ...M (Column 8, Line 25 to Column 9, Line 26; Columns 11-12). Sallas discloses activating all vibrators and using at least one detector to detect and record the combined seismic response signals from all vibrators. Sallas discloses selecting and recording a signature for each vibrator indicative of the motion of that vibrator (Column 2; Column 5, Line 59 to Column 6, Line 6; Column 7, Line 22 to Column 8, Line 65; Columns 11-12).

Claim 20 lacks an inventive step under PCT Article 33(3) as being obvious over Anderson.
With regard to claim 20, Anderson discloses a method of operating N seismic vibrators simultaneously with continuous sweeps, so that the seismic response of each vibrator can be separated (abstract; Column 4, Line 20 to Column 5, Line 20; Column 8) (Anderson teaches encoded signals and correlation and vibrator sweet sequences). Anderson discloses only one vibrator, but is obvious from the disclosure that more than vibrator could be used, each of which employs the same method disclosed. Anderson discloses loading each vibrator with a unique continuous sweep signal consisting of M greater than or equal to N segments, the ith segment being of the same duration for each vibrator with i=1, 2, ...M (Column 4, Line 210 to Column 5, Line 50; Column 6). Anderson discloses activating all vibrators and using at least one detector to detect and record the combined seismic response signals from all vibrators (Column 1; Column 4, Line 20 to Column 5, Line 20). Anderson discloses selecting and recording a signature for each vibrator indicative of the motion of that vibrator (Figs. 6, 7, 8a,b,c) (Column 4, Line 20 to Column 5, Line 50; Column 6; Column 15).

------------------ NEW CITATIONS ------------------

Form PCT/IPEA/409 (Box No. V) (April 2005)

comprising the steps of deriving a separation and inversion filter of the form $F = (S^* S)^{-1} S^*$, then performing the matrix multiplication $F\tilde{D}$.

9. The method of claim 1, wherein each segment has a duration that is at least as long as the seismic wave travel time down to and back up from the deepest reflector of interest.

10. A method of separating the seismic response for each of a plurality N of seismic vibrators operated simultaneously with continuous sweeps, said method comprising the steps of:

(a) obtaining a seismic data record of the combined response signals from all vibrators as detected and recorded by at least one detector, each vibrator having been loaded with a unique continuous sweep signal consisting of $M \geq N$ segments, the i^{th} segment being of the same duration for each vibrator, $i = 1, 2, \ldots, M$;

(b) obtaining a vibrator motion record for each vibrator containing a signature for each vibrator indicative of the motion of that vibrator;

(c) parsing the vibrator motion record for each vibrator into M shorter records, each shorter record coinciding in time with a sweep segment, and then padding the end of each shorter record sufficiently to extend its duration by substantially one listening time;

(d) forming an $M \times N$ matrix s whose element $s_{ij}(t)$ is the padded shorter vibrator motion record as a function of time t for the i^{th} vibrator and j^{th} sweep segment;

(e) parsing the seismic data record from step (a) into M shorter records, each shorter record coinciding in time with a padded shorter record of vibrator motion from step (c);

(f) forming a vector $\vec{d}$ of length M whose element d_i is the i^{th} shorter data record from the preceding step;

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IPEA/US 08 FEB 2006

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(g) solving for $E_j(f)$ the following system of M linear equations in N unknowns

$$S\vec{E} = \vec{D}$$

where $S_{ij}(f)$ is the Fourier transform to the frequency (f) domain of $s_{ij}(t)$ and $D_i(f)$ is the Fourier transform of $d_i(t)$, where $i = 1, 2, \ldots M$ and $j = 1, 2, \ldots N$; and

(h) inverse Fourier transforming the $E_j(f)$ to yield $e_j(t)$.

11. A method of operating a plurality N of seismic vibrators simultaneously with continuous sweeps, so that the seismic response for each vibrator can be separated, said method comprising the steps of:

(a) loading each vibrator with a unique continuous sweep signal consisting of $M \geq N$ segments, the i^{th} segment being of the same duration for each vibrator, $i = 1, 2, \ldots, M$;

(b) activating all vibrators and using at least one detector to detect and record the combined seismic response signals from all vibrators;

(c) selecting and recording a signature for each vibrator indicative of the motion of that vibrator; and

(d) sending the vibrator motion record for each vibrator and the seismic data record to be processed by

parsing the vibrator motion record for each vibrator into M shorter records, each shorter record coinciding in time with a sweep segment, and then

padding the end of each shorter record sufficiently to extend its duration by substantially one listening time;

forming an $M \times N$ matrix s whose element $s_{ij}(t)$ is the padded shorter vibrator motion record as a function of time t for the i^{th} vibrator and j^{th} sweep segment;

parsing the seismic data record from step (b) into M shorter records, each shorter record coinciding in time with a padded shorter record of vibrator motion;

forming a vector $\vec{d}$ of length M whose element d_i is the i^{th} shorter data record;

AMENDED SHEET

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IPEA/US 08 FEB 2006

19/2

solving for $E_j(f)$ the following system of M linear equations in N unknowns

$$S\bar{E} = \bar{D}$$

where $S_{ij}(f)$ is the Fourier transform to the frequency (f) domain of $s_{ij}(t)$ and $D_i(f)$ is the Fourier transform of $d_i(t)$, where $i = 1, 2, \ldots M$ and $j = 1, 2, \ldots N$; and

inverse Fourier transforming the $E_j(f)$ to yield $e_j(t)$.

12. The method of claim 10 or claim 11, wherein each sweep segment is selected from one of the following sweep-design categories: (a) linear, (b) nonlinear, and (c) pseudo-random.

13. The method of claim 10 or claim 11, wherein all of the N unique continuous sweeps are identical except for the phase of their segments.

14. The method of claim 13, wherein all N segments are identical except for phase, and the phase differences for the N sweeps are determined by the following steps: (a) constructing a reference sweep by starting with a preselected reference segment, then advancing the segment $360/M$ degrees in phase to make the second segment, then advancing the phase $360/M$ more degrees to make the third segment, and so on to generate a sweep of M segments; (b) constructing a first sweep by advancing the phase of the first segment of the reference sweep by 90 degrees; (c) constructing a second sweep by advancing the phase of the second segment of the reference sweep by 90 degrees; (d) and so on until N sweeps are constructed.

15. The method of claim 10 or claim 11, wherein each unique continuous sweep has a duration in time sufficiently long to collect all seismic data desired before relocating the vibrators.

16. The method of claim 10 or claim 11, wherein the vibrator signature record for each vibrator is a weighted sum or ground force record of the motion of that vibrator.

AMENDED SHEET

17. The method of claim 10 or claim 11, wherein $M = N$ and the system of linear equations $S\bar{E} = \bar{D}$ is solved by matrix methods comprising the steps of deriving a separation and inversion filter $(S)^{-1}$ by inverting the matrix S, then performing the matrix multiplication $(S)^{-1}\bar{D}$.

18. The method of claim 10 or claim 11, wherein the system of linear equations $S\bar{E} = \bar{D}$ is solved by matrix methods and the method of least squares comprising the steps of deriving a separation and inversion filter of the form $F = (S^{*}S)^{-1}S^{*}$, then performing the matrix multiplication $F\bar{D}$.

19. The method of claim 10 or claim 11, wherein each segment has a duration that is at least as long as the seismic wave travel time down to and back up from the deepest reflector of interest.

20. method of operating a plurality N of seismic vibrators simultaneously with continuous sweeps, so that the seismic response for each vibrator can be separated, said method comprising the steps of:

(a) loading each vibrator with a unique continuous sweep signal consisting of $M \geq N$ segments, the i^{th} segment being of the same duration for each vibrator, $i = 1, 2, \ldots, M$;

(b) activating all vibrators and using at least one detector to detect and record the combined seismic response signals from all vibrators; and

(c) selecting and recording a signature for each vibrator indicative of the motion of that vibrator.

21. A method of separating the seismic response for each of a plurality N of seismic vibrators operated simultaneously with continuous sweeps, said method comprising the steps of:

(a) parsing the vibrator motion record for each vibrator into M shorter records, each shorter record coinciding in time with a sweep segment, and then

AMENDED SHEET

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IPEA/US 08 FEB 2006

padding the end of each shorter record sufficiently to extend its duration by substantially one listening time;

(b) forming an M x N matrix s whose element $s_{ij}(t)$ is the padded shorter vibrator motion record as a function of time t for the i^{th} vibrator and j^{th} sweep segment;

(c) parsing the seismic data record from step (b) into M shorter records, each shorter record coinciding in time with a padded shorter record of vibrator motion;

(d) forming a vector $\vec{d}$ of length M whose element d_i is the i^{th} shorter data record from the preceding step;

(e) solving for $E_j(f)$ the following system of M linear equations in N unknowns

$$S\vec{E} = \vec{D}$$

where $S_{ij}(f)$ is the Fourier transform to the frequency (f) domain of $s_{ij}(t)$ and $D_i(f)$ is the Fourier transform of $d_i(t)$, where $i = 1, 2, \ldots M$ and $j = 1, 2, \ldots N$; and

(f) inverse Fourier transforming the $E_j(f)$ to yield $e_j(t)$.

AMENDED SHEET

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PATENT COOPERATION TREATY

IN THE UNITED STATES RECEIVING OFFICE

Applicant's File Reference	Authorized Officer	Date
2003UR020	Scott Hughes	February 6, 2006
International Application No.	International filing date (day/month/year)	Priority date (day/month/year)
PCT/US04/17335	03 June 2004 (03/06/2004)	11 August 2003 (11/08/2003)
Applicant		
EXXONMOBIL UPSTREAM RESEARCH COMPANY		
Title of the Invention		
METHOD FOR CONTINUOUS SWEEPING AND SEPARATION OF MULTIPLE SEISMIC VIBRATORS		

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RESPONSE TO WRITTEN OPINION MAILED JANUARY 3, 2006

This communication is a response under PCT Article 34 to the Written Opinion of the International Searching Authority mailed January 3, 2006.

In the Written Opinion, the examiner contends that U.S. Patent No. 5,410,517 ("Andersen") and PCT patent publication WO 01/61379 ("Jeffryes") combine to make the claims of the present application obvious. Applicant respectfully disagrees, and will show below that the examiner has misunderstood the teachings of the present application, or of the two prior art references, or both.

Among other features, the present invention is a method for (a) separating the seismic responses due to a plurality of simultaneously operating vibrators while (b) eliminating unproductive listening time between consecutive vibrator sweeps. Andersen explains the problem of unproductive listening time at col. 2, lines 15-33;

see also paragraph 12 of the present application. As Jeffryes explains at page 1, lines 22-27, when multiple simultaneous vibrators are used, it is preferable to separate the data recorded at each receiver into the separate contributions due to each individual vibrator.

Andersen discloses a method (different from Applicant's method) for eliminating listen time, but does not disclose any method for separating multiple vibrator responses. Jeffryes discloses a method for separating multiple vibrator responses (different from Applicant's method), but does not disclose any way to eliminate listening time. The two references combined neither teach nor suggest Applicant's method.

The examiner has confused the sweep segment of Applicant's invention with Jeffryes's "sweep." Applicants' sweep segments are combined to form a single "sweep" because they require no dead time between segments, and in preferred embodiments, have no dead time for listening, equipment recovery or any other reason. Applicant is able nevertheless to separate the response in key part because of Applicant's parsing step (neither disclosed nor suggested in either reference). The examiner contends that Jeffryes discloses Applicant's parsing step, but this is a misunderstanding. Jeffryes does not do so, and furthermore has no reason to do so because his n separate records are naturally defined with no loss of data by including the listening time after each shot or sweep.

The reader must exercise a little judgment in reading Jeffryes to realize that he does not suggest eliminating the listen time, and in fact relies on it to define his n separate data records. Jeffryes never mentions listening time, because he does not intend to depart from the customary vibrator technique of separating consecutive sweeps by a listening time so that the full response from each sweep may be captured. A copy of a page from Sheriff's Encyclopedic Dictionary of Applied Geophysics, 4th Ed., published by the Society of Exploration Geophysicists, is enclosed. It contains an illustration of a typical vibroseis record (Fig. V-12). It can easily be seen that the response ("return") continues for a period of time after the sweep signal is finished. As stated above, Andersen's column 2, lines 15-33 provide ample authority for the typical practice of following each sweep by a listen period during which the vibrator is

not sweeping. Figure V-12 shows why such a listening period is used, as does Jeffryes's Fig. 1. If Jeffryes's separate sweeps were stacked end-to end with no listening time, his data records would not be complete because he discloses no way to extend them to include the response lag at the end of each sweep. His method, with no listen time, would use data records that would necessarily be incomplete.

Andersen's method cannot be combined with Jeffryes's method to solve this listening time problem. Andersen can eliminate listening time because he is not trying to separate records from multiple vibrators, for which it is important to capture the full response for each sweep. There is nothing in Andersen about separating records from multiple vibrators. Multiple vibrators can be used in Andersen's method to increase the energy transmitted into the ground, but all vibrators in such an embodiment would be shaking the same, driven by the same sweep signal, and there would be no attempt to separate the summed seismic response. This introduces inaccuracies in the data, which is why Applicant and others have developed ways to separate the data. Furthermore, it is noted that the examiner uses Andersen in connection with the data processing steps of Applicant's claim 1, and not in connection with the data acquisition steps. It is not surprising that Andersen provides nothing of relevance in such combination with Jeffryes because Applicant's claim 1 uses an inversion method for processing the vibrator data (see paragraph 8 on page 4 of the present application), which is a fundamentally different approach than the traditional correlation method of processing vibroseis data that Andersen uses (see Andersen, col. 1, line 54 to col. 2, line 3).

In the end, it is sufficient that neither of the references discloses or suggests steps (d) and (f) in Applicant's claim 1. In step (f), when the seismic data record is parsed into M shorter records, a portion of each shorter record is reused in the next shorter record, i.e., the last few seconds of the one record is also used as the first few seconds of the next. Thus, Applicant's parsing is not merely dividing the record into contiguous, non-overlapping segments, such as the segments of the vibrator sweep described in step (a) of claim 1. This type of parsing is neither disclosed nor suggested in Jeffryes or Andersen.

In view of the preceding, Applicant requests that the examiner reissue the Written Opinion, finding that all claims have inventive step. If there are questions, please contact the undersigned at 713-431-7360.

For reasons unrelated to the prior art, and instead related to territorial limitations in patent enforcement, Applicant submits herewith amended claims under Article 34. The nine original claims remain unchanged (Claims 1-9). They are followed by twelve new claims. In independent claims 10 and 11, Applicant believes there is no new matter problem because the only effect is to reorganize the wording of claim 1 in ways that neither add nor delete any limitations. Dependent claims 12-19 are identical to claims 2-9 except that they depend off of claims 10 or 11 instead of claim 1. Claims 20 and 21 are independent claims for which there should be no new matter issue because they result from partitioning claim 1 except for minor word variations, Applicants believing that both the data acquisition first part of claim 1 and the data processing last part of claim 1 are separately patentable. A complete listing of the claims, as amended, is included.

Respectfully submitted,

Date: February 8, 2006

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Monica Stansberry

Monica J. Stansberry

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CLAIMS

What is claimed is:

1. *(Original)* A method of operating a plurality N of seismic vibrators simultaneously with continuous sweeps, and separating the seismic response for each vibrator, said method comprising the steps of:

(a) loading each vibrator with a unique continuous sweep signal consisting of $M \geq N$ segments, the i^{th} segment being of the same duration for each vibrator, $i = 1, 2, \ldots, M$;

(b) activating all vibrators and using at least one detector to detect and record the combined seismic response signals from all vibrators;

(c) selecting and recording a signature for each vibrator indicative of the motion of that vibrator;

(d) parsing the vibrator motion record for each vibrator into M shorter records, each shorter record coinciding in time with a sweep segment, and then padding the end of each shorter record sufficiently to extend its duration by substantially one listening time;

(e) forming an M x N matrix s whose element $s_{ij}(t)$ is the padded shorter vibrator motion record as a function of time t for the i^{th} vibrator and j^{th} sweep segment;

(f) parsing the seismic data record from step (b) into M shorter records, each shorter record coinciding in time with a padded shorter record of vibrator motion from step (d);

(g) forming a vector $\vec{d}$ of length M whose element d_i is the i^{th} shorter data record from the preceding step;

(h) solving for $E_j(f)$ the following system of M linear equations in N unknowns

$$S\vec{E} = \vec{D}$$

where $S_{ij}(f)$ is the Fourier transform to the frequency (f) domain of $s_{ij}(t)$ and $D_i(f)$ is the Fourier transform of $d_i(t)$, where $i = 1, 2, \ldots M$ and $j = 1, 2, \ldots N$; and

(i) inverse Fourier transforming the $E_j(f)$ to yield $e_j(t)$.

2. *(Original)* The method of claim 1, wherein each sweep segment is selected from one of the following sweep-design categories: (a) linear, (b) nonlinear, and (c) pseudo-random.

3. *(Original)* The method of claim 1, wherein all of the N unique continuous sweeps are identical except for the phase of their segments.

4. *(Original)* The method of claim 3, wherein all N segments are identical except for phase, and the phase differences for the N sweeps are determined by the following steps: (a) constructing a reference sweep by starting with a preselected reference segment, then advancing the segment 360/M degrees in phase to make the second segment, then advancing the phase 360/M more degrees to make the third segment, and so on to generate a sweep of M segments; (b) constructing a first sweep by advancing the phase of the first segment of the reference sweep by 90 degrees; (c) constructing a second sweep by advancing the phase of the second segment of the reference sweep by 90 degrees; (d) and so on until N sweeps are constructed.

5. *(Original)* The method of claim 1, wherein each unique continuous sweep has a duration in time sufficiently long to collect all seismic data desired before relocating the vibrators.

6. *(Original)* The method of claim 1, wherein the vibrator signature record for each vibrator is a weighted sum or ground force record of the motion of that vibrator.

7. *(Original)* The method of claim 1, wherein $M = N$ and the system of linear equations $\mathbf{S}\vec{E} = \vec{D}$ is solved by matrix methods comprising the steps of deriving a separation and inversion filter $(S)^{-1}$ by inverting the matrix S, then performing the matrix multiplication $(\mathbf{S})^{-1}\vec{D}$.

8. *(Original)* The method of claim 1, wherein the system of linear equations $\mathbf{S}\vec{E} = \vec{D}$ is solved by matrix methods and the method of least squares

comprising the steps of deriving a separation and inversion filter of the form $\mathbf{F} = \left(\mathbf{S}^{*}\mathbf{S}\right)^{-1}\mathbf{S}^{*}$, then performing the matrix multiplication $\mathbf{F}\bar{D}$.

9. *(Original)* The method of claim 1, wherein each segment has a duration that is at least as long as the seismic wave travel time down to and back up from the deepest reflector of interest.

10. *(New)* A method of separating the seismic response for each of a plurality N of seismic vibrators operated simultaneously with continuous sweeps, said method comprising the steps of:

(a) obtaining a seismic data record of the combined response signals from all vibrators as detected and recorded by at least one detector, each vibrator having been loaded with a unique continuous sweep signal consisting of $M \geq N$ segments, the i^{th} segment being of the same duration for each vibrator, $i = 1, 2, \ldots, M$;

(b) obtaining a vibrator motion record for each vibrator containing a signature for each vibrator indicative of the motion of that vibrator;

(c) parsing the vibrator motion record for each vibrator into M shorter records, each shorter record coinciding in time with a sweep segment, and then padding the end of each shorter record sufficiently to extend its duration by substantially one listening time;

(d) forming an M x N matrix s whose element $s_{ij}(t)$ is the padded shorter vibrator motion record as a function of time t for the i^{th} vibrator and j^{th} sweep segment;

(e) parsing the seismic data record from step (a) into M shorter records, each shorter record coinciding in time with a padded shorter record of vibrator motion from step (c);

(f) forming a vector $\vec{d}$ of length M whose element d_i is the i^{th} shorter data record from the preceding step;

(g) solving for $E_j(f)$ the following system of M linear equations in N unknowns

$$S\vec{E} = \vec{D}$$

where $S_{ij}(f)$ is the Fourier transform to the frequency (f) domain of $s_{ij}(t)$ and $D_i(f)$ is the Fourier transform of $d_i(t)$, where $i = 1, 2, \ldots M$ and $j = 1, 2, \ldots N$; and

(h) inverse Fourier transforming the $E_j(f)$ to yield $e_j(t)$.

11. *(New)* A method of operating a plurality N of seismic vibrators simultaneously with continuous sweeps, so that the seismic response for each vibrator can be separated, said method comprising the steps of:

(a) loading each vibrator with a unique continuous sweep signal consisting of $M \geq N$ segments, the i^{th} segment being of the same duration for each vibrator, $i = 1, 2, \ldots, M$;

(b) activating all vibrators and using at least one detector to detect and record the combined seismic response signals from all vibrators;

(c) selecting and recording a signature for each vibrator indicative of the motion of that vibrator; and

(d) sending the vibrator motion record for each vibrator and the seismic data record to be processed by

parsing the vibrator motion record for each vibrator into M shorter records, each shorter record coinciding in time with a sweep segment, and then

padding the end of each shorter record sufficiently to extend its duration by substantially one listening time;

forming an M x N matrix s whose element $s_{ij}(t)$ is the padded shorter vibrator motion record as a function of time t for the i^{th} vibrator and j^{th} sweep segment;

parsing the seismic data record from step (b) into M shorter records, each shorter record coinciding in time with a padded shorter record of vibrator motion;

forming a vector $\vec{d}$ of length M whose element d_i is the i^{th} shorter data record;

solving for $E_j(f)$ the following system of M linear equations in N unknowns

$$S\vec{E} = \vec{D}$$

where $S_{ij}(f)$ is the Fourier transform to the frequency (f) domain of $s_{ij}(t)$ and $D_i(f)$ is the Fourier transform of $d_i(t)$, where $i = 1, 2, \ldots M$ and $j = 1, 2, \ldots N$; and

inverse Fourier transforming the $E_j(f)$ to yield $e_j(t)$.

12. *(New)* The method of claim 10 or claim 11, wherein each sweep segment is selected from one of the following sweep-design categories: (a) linear, (b) nonlinear, and (c) pseudo-random.

13. *(New)* The method of claim 10 or claim 11, wherein all of the N unique continuous sweeps are identical except for the phase of their segments.

14. *(New)* The method of claim 13, wherein all N segments are identical except for phase, and the phase differences for the N sweeps are determined by the following steps: (a) constructing a reference sweep by starting with a preselected reference segment, then advancing the segment 360/M degrees in phase to make the second segment, then advancing the phase 360/M more degrees to make the third segment, and so on to generate a sweep of M segments; (b) constructing a first sweep by advancing the phase of the first segment of the reference sweep by 90 degrees; (c) constructing a second sweep by advancing the phase of the second segment of the reference sweep by 90 degrees; (d) and so on until N sweeps are constructed.

15. *(New)* The method of claim 10 or claim 11, wherein each unique continuous sweep has a duration in time sufficiently long to collect all seismic data desired before relocating the vibrators.

16. *(New)* The method of claim 10 or claim 11, wherein the vibrator signature record for each vibrator is a weighted sum or ground force record of the motion of that vibrator.

17. *(New)* The method of claim 10 or claim 11, wherein $M = N$ and the system of linear equations $S\vec{E} = \vec{D}$ is solved by matrix methods comprising the steps of deriving a separation and inversion filter $(S)^{-1}$ by inverting the matrix S, then performing the matrix multiplication $(S)^{-1}\vec{D}$.

18. *(New)* The method of claim 10 or claim 11, wherein the system of linear equations $S\vec{E} = \vec{D}$ is solved by matrix methods and the method of least squares comprising the steps of deriving a separation and inversion filter of the form $F = (S^{*}S)^{-1}S^{*}$, then performing the matrix multiplication $F\vec{D}$.

19. *(New)* The method of claim 10 or claim 11, wherein each segment has a duration that is at least as long as the seismic wave travel time down to and back up from the deepest reflector of interest.

20. *(New)* A method of operating a plurality N of seismic vibrators simultaneously with continuous sweeps, so that the seismic response for each vibrator can be separated, said method comprising the steps of:

(a) loading each vibrator with a unique continuous sweep signal consisting of $M \geq N$ segments, the i^{th} segment being of the same duration for each vibrator, $i = 1, 2, \ldots, M$;

(b) activating all vibrators and using at least one detector to detect and record the combined seismic response signals from all vibrators; and

(c) selecting and recording a signature for each vibrator indicative of the motion of that vibrator.

21. *(New)* A method of separating the seismic response for each of a plurality N of seismic vibrators operated simultaneously with continuous sweeps, said method comprising the steps of:

(a) parsing the vibrator motion record for each vibrator into M shorter records, each shorter record coinciding in time with a sweep segment, and then

padding the end of each shorter record sufficiently to extend its duration by substantially one listening time;

(b) forming an $M \times N$ matrix s whose element $s_{ij}(t)$ is the padded shorter vibrator motion record as a function of time t for the i^{th} vibrator and j^{th} sweep segment;

(c) parsing the seismic data record from step (b) into M shorter records, each shorter record coinciding in time with a padded shorter record of vibrator motion;

(d) forming a vector $\vec{d}$ of length M whose element d_i is the i^{th} shorter data record from the preceding step;

(e) solving for $E_j(f)$ the following system of M linear equations in N unknowns

$$S\bar{E} = \bar{D}$$

where $S_{ij}(f)$ is the Fourier transform to the frequency (f) domain of $s_{ij}(t)$ and $D_i(f)$ is the Fourier transform of $d_i(t)$, where $i = 1, 2, \ldots M$ and $j = 1, 2, \ldots N$; and

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2. *(Original)* The method of claim 1, wherein each sweep segment is selected from one of the following sweep-design categories: (a) linear, (b) nonlinear, and (c) pseudo-random.

3. *(Original)* The method of claim 1, wherein all of the N unique continuous sweeps are identical except for the phase of their segments.

4. *(Original)* The method of claim 3, wherein all N segments are identical except for phase, and the phase differences for the N sweeps are determined by the following steps: (a) constructing a reference sweep by starting with a preselected reference segment, then advancing the segment $360/M$ degrees in phase to make the second segment, then advancing the phase $360/M$ more degrees to make the third segment, and so on to generate a sweep of M segments; (b) constructing a first sweep by advancing the phase of the first segment of the reference sweep by 90 degrees; (c) constructing a second sweep by advancing the phase of the second segment of the reference sweep by 90 degrees; (d) and so on until N sweeps are constructed.

5. *(Original)* The method of claim 1, wherein each unique continuous sweep has a duration in time sufficiently long to collect all seismic data desired before relocating the vibrators.

6. *(Original)* The method of claim 1, wherein the vibrator signature record for each vibrator is a weighted sum or ground force record of the motion of that vibrator.

7. *(Original)* The method of claim 1, wherein $M = N$ and the system of linear equations $\mathbf{S}\vec{E} = \vec{D}$ is solved by matrix methods comprising the steps of deriving a separation and inversion filter $(S)^{-1}$ by inverting the matrix S, then performing the matrix multiplication $(\mathbf{S})^{-1}\vec{D}$.

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9. *(Original)* The method of claim 1, wherein each segment has a duration that is at least as long as the seismic wave travel time down to and back up from the deepest reflector of interest.

10. *(New)* A method of separating the seismic response for each of a plurality N of seismic vibrators operated simultaneously with continuous sweeps, said method comprising the steps of:

(a) obtaining a seismic data record of the combined response signals from all vibrators as detected and recorded by at least one detector, each vibrator having been loaded with a unique continuous sweep signal consisting of $M \geq N$ segments, the i^{th} segment being of the same duration for each vibrator, $i = 1, 2, \ldots, M$;

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(c) parsing the vibrator motion record for each vibrator into M shorter records, each shorter record coinciding in time with a sweep segment, and then padding the end of each shorter record sufficiently to extend its duration by substantially one listening time;

(d) forming an M x N matrix s whose element $s_{ij}(t)$ is the padded shorter vibrator motion record as a function of time t for the i^{th} vibrator and j^{th} sweep segment;

(e) parsing the seismic data record from step (a) into M shorter records, each shorter record coinciding in time with a padded shorter record of vibrator motion from step (c);

(f) forming a vector $\vec{d}$ of length M whose element d_i is the i^{th} shorter data record from the preceding step;

(g) solving for $E_j(f)$ the following system of M linear equations in N unknowns

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where $S_{ij}(f)$ is the Fourier transform to the frequency (f) domain of $s_{ij}(t)$ and $D_i(f)$ is the Fourier transform of $d_i(t)$, where $i = 1, 2, \ldots M$ and $j = 1, 2, \ldots N$; and

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parsing the vibrator motion record for each vibrator into M shorter records, each shorter record coinciding in time with a sweep segment, and then

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parsing the seismic data record from step (b) into M shorter records, each shorter record coinciding in time with a padded shorter record of vibrator motion;

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14. *(New)* The method of claim 13, wherein all N segments are identical except for phase, and the phase differences for the N sweeps are determined by the following steps: (a) constructing a reference sweep by starting with a preselected reference segment, then advancing the segment 360/M degrees in phase to make the second segment, then advancing the phase 360/M more degrees to make the third segment, and so on to generate a sweep of M segments; (b) constructing a first sweep by advancing the phase of the first segment of the reference sweep by 90 degrees; (c) constructing a second sweep by advancing the phase of the second segment of the reference sweep by 90 degrees; (d) and so on until N sweeps are constructed.

PAGE 34/36 * RCVD AT 8/10/2007 4:27:28 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/21 * DNIS:2738300 * CSID:713 431 4664 * DURATION (mm-ss):13-02

15. *(New)* The method of claim 10 or claim 11, wherein each unique continuous sweep has a duration in time sufficiently long to collect all seismic data desired before relocating the vibrators.

16. *(New)* The method of claim 10 or claim 11, wherein the vibrator signature record for each vibrator is a weighted sum or ground force record of the motion of that vibrator.

17. *(New)* The method of claim 10 or claim 11, wherein $M = N$ and the system of linear equations $S\vec{E} = \vec{D}$ is solved by matrix methods comprising the steps of deriving a separation and inversion filter $(S)^{-1}$ by inverting the matrix S, then performing the matrix multiplication $(S)^{-1}\vec{D}$.

18. *(New)* The method of claim 10 or claim 11, wherein the system of linear equations $S\vec{E} = \vec{D}$ is solved by matrix methods and the method of least squares comprising the steps of deriving a separation and inversion filter of the form $F = (S^{*}S)^{-1}S^{*}$, then performing the matrix multiplication $F\vec{D}$.

19. *(New)* The method of claim 10 or claim 11, wherein each segment has a duration that is at least as long as the seismic wave travel time down to and back up from the deepest reflector of interest.

20. *(New)* A method of operating a plurality N of seismic vibrators simultaneously with continuous sweeps, so that the seismic response for each vibrator can be separated, said method comprising the steps of:

(a) loading each vibrator with a unique continuous sweep signal consisting of $M \geq N$ segments, the i^{th} segment being of the same duration for each vibrator, $i = 1, 2, \ldots, M$;

(b) activating all vibrators and using at least one detector to detect and record the combined seismic response signals from all vibrators; and

(c) selecting and recording a signature for each vibrator indicative of the motion of that vibrator.

21. *(New)* A method of separating the seismic response for each of a plurality N of seismic vibrators operated simultaneously with continuous sweeps, said method comprising the steps of:

(a) parsing the vibrator motion record for each vibrator into M shorter records, each shorter record coinciding in time with a sweep segment, and then padding the end of each shorter record sufficiently to extend its duration by substantially one listening time;

(b) forming an M x N matrix s whose element $s_{ij}(t)$ is the padded shorter vibrator motion record as a function of time t for the i^{th} vibrator and j^{th} sweep segment;

(c) parsing the seismic data record from step (b) into M shorter records, each shorter record coinciding in time with a padded shorter record of vibrator motion;

(d) forming a vector $\vec{d}$ of length M whose element d_i is the i^{th} shorter data record from the preceding step;

(e) solving for $E_j(f)$ the following system of M linear equations in N unknowns

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where $S_{ij}(f)$ is the Fourier transform to the frequency (f) domain of $s_{ij}(t)$ and $D_i(f)$ is the Fourier transform of $d_i(t)$, where $i = 1, 2, \ldots M$ and $j = 1, 2, \ldots N$; and

(f) inverse Fourier transforming the $E_j(f)$ to yield $e_j(t)$.